CHAPTER 5

MOTOR CONTROLS

5-1. Functions of motor controls.

The terms, controls, controllers, and starters are used interchangeably. The most common name for the device that controls the operation of the motor is starter. This name is not the best description of the device as the starter does much more than start the motor. It also stops the motor, it provides overload and short circuit protection, and it disconnects the motor from the line after a period of overcurrent. It may also contain auxiliary devices that limit the motor inrush current, torque, and/or speed. Additional protection features may include undervoltage, phase reversal, and/or field loss.

5-2. Types of motor controls.

Some of the more common motor starters are described in this chapter beginning with the elementary document starter and ending with the more complex adjustable speed frequency starter.

a. *Document across-the-line starters.* Document starters are most often used on small single phase fractional horsepower motors. They usually consist of a push button-type or a toggle-type mechanism (fig 5-1) that actuates a set of quick-make/quick-break contacts that connect the motor directly to the line. Document starters have provisions for overload protection and their low cost provides economical starter selection for applications where no undervoltage protection is required.

b. *Magnetic across-the-line starters.* Magnetic starters are suitable for application over a wide range of horsepower and voltage for both single and three phase motors. Magnetic starters are full voltage starters designed to provide thermal overload and undervoltage protection for squirrel cage motors and can be operated remotely from push button stations or automatically, for example, through a float switch. They differ from document starters in that they contain a contactor which, when its electromagnetic coil is energized, closes its line contacts to connect the motor directly to the line (fig 5-2). The primary purpose of a motor starter is to provide thermal overload protection, it is not designed to interrupt fault current. A short circuit study must always be performed to determine if protection is necessary from fault currents and, if so, short circuit protection must be provided. A circuit breaker, or fuses, upline of the contactor gives fault current protection to the starter and the motor. Starters must always include thermal overload relays. Exceptions are noted in NEC 430. Starters without overloads are called contractors. The holding coil of a magnetic starter (or contactor) is designed to drop out whenever line voltage drops below about 60 percent of its normal value, thereby providing undervoltage protection to the motor or load.

c. *Combination starters.* All motors, motor circuits and controllers require short-circuit and ground-fault protection. This may be located with the starter as in a combination starter or may be the branch-circuit short-circuit and ground-fault protective device as in a manual motor starter. (NEC 430, part D). Starters connected to a power distribution system with an available fault current in excess of the starter short circuit interrupting capacity must be protected from that fault current. Combining a contactor with a thermal overload relay is called a magnetic motor starter and combining a magnetic motor starter with a circuit breaker or fuses in a common enclosure is called a combination starter. These starters carry an interrupting rating that indicates the ability of all components in the integrated combination starter to withstand momentary overcurrent and thermal effects. Depending upon the type of short-circuit protective device employed, combination starters (fig 5-3) may be classified as breaker-protected starters, fuse-protected starters or fused breaker-protected starters.

(1) *Breaker-protected starters.* Breaker-protected starters use almost exclusively molded-case breakers. Low voltage power circuit breakers have sometimes been applied, especially for use on larger motors- Breakers, as compared to fuses, are slower in fault clearing for higher magnitudes of short circuit currents. Consequently, three pole breakers afford the least protection against thermal overload relay and contactor damage. However, they offer positive protection against single phasing. Breakers are usually designed for both thermal and magnetic protection even though the overloads are the best thermal protection because overload relay heaters can be very closely selected to cause tripping at precise values of current flow. Motor circuit protectors (MCPs) used in combination starters are magnetic trip only and have no thermal trip device.

(2) *Fuse-protected starters.* Fuse-protected starters provide the best degree of starter and thermal overload relay protection particularly for severe short circuits (fig 5-4). The disadvantages of fused-

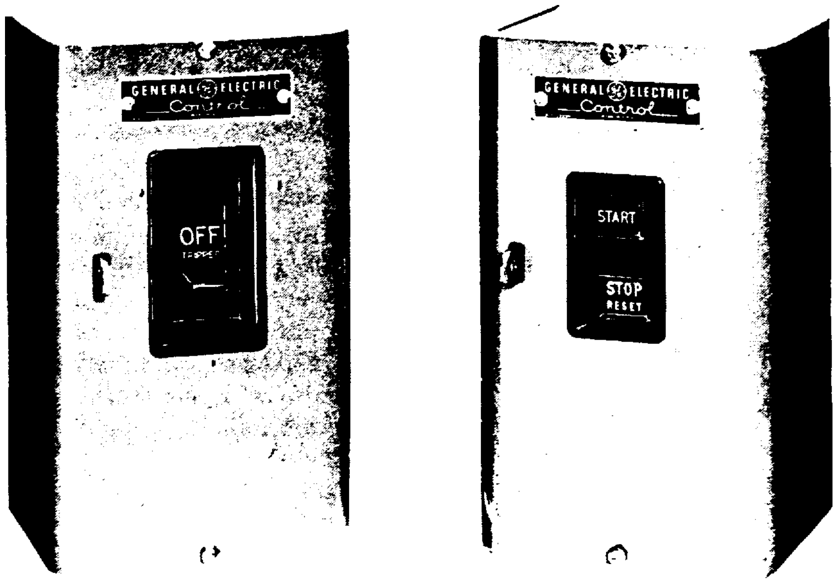


Figure 5-1. Manual starters

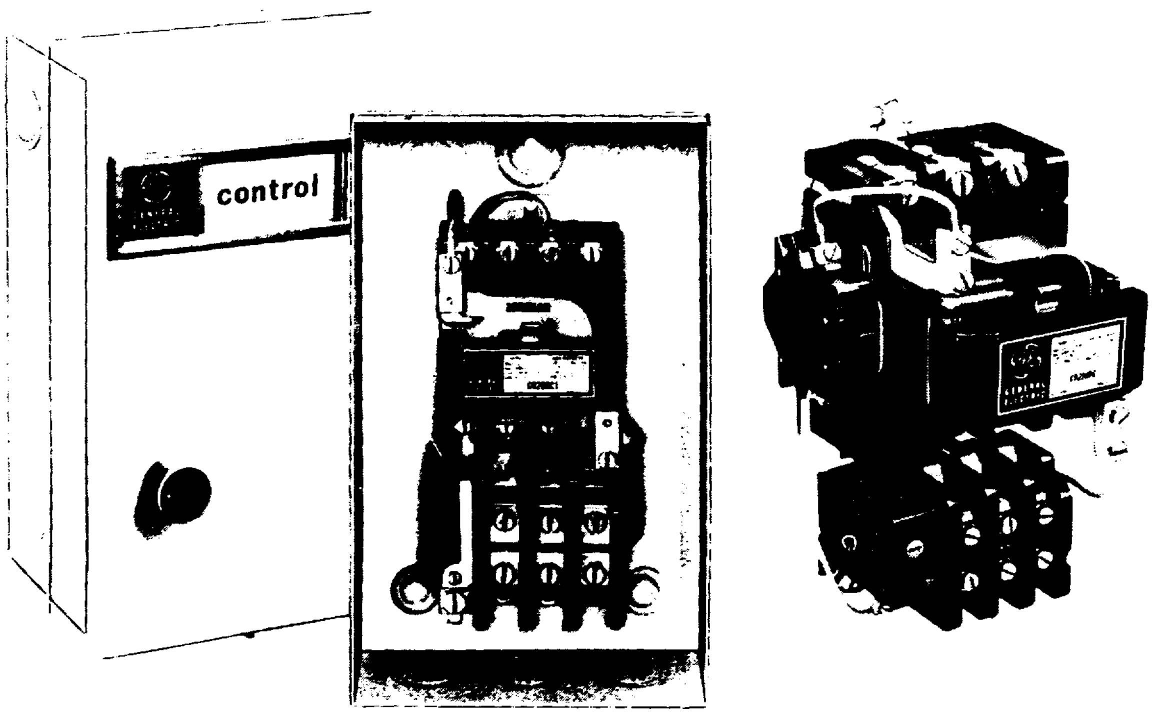


Figure 5-2. Typical magnetic starter

combination starters are possible single-phasing and incorrect replacement of fuses.

(3) *Fused breaker-protected starters.* Fused breaker-protected starters use a specific current-limiting fuse to back up a breaker of specified type and make to obtain a higher interrupting rating for the combination while maintaining the advantages of three-phase interrupters.

d. Reduced voltage starters. Reduced voltage starters provide power to motors at lower starting voltages resulting in reduced inrush currents and reduced starting torques. Several types of starters are discussed below.

(1) *Autotransformer starters.* These starters generally insert autotransformers or reactors in series with the motor windings to limit starting cur-

Table 15-3. Interior wiring and lighting system.

RESPONSIBILITY	FREQUENCY	CHECK	REF.
Maintenance Group (Operator/ Electricians	Each scheduled building visit	Unauthorized or nonstandard attachments Defective convenience outlets and switches. Improper cords. Proper fuse sizes in panels. Overheating of panels. Any condition likely to cause fire. Check battery-type emergency lights and replacement lamps. Check for Iamps larger than standard prescribed for outlet. Replace burnt out lamps in hard-to-reach places. (To be accomplished by electrical shop if special equipment such as ladder trucks are needed).	 5-4-4 9-7 9-6
User	As Required	Panels for circuit idenificaton and accessibility. Replace blown fuses. Replace burnt out or defective incandescent lamps. Replace burnt out fluorescent lamps if personnel have been instructed in this function and if assigned to user. Promptly replace or report defective lamps since a lamp approaching bum out flashes on and off, causing overduty on auxiliary equipment.	5-4-1 5-4-4 9-6 9-6
Electrician	As required.	Make repairs **and** adjustments to systems when malfunctions are reported. Ensure that all work complies with the NEC	
Electrician	As required.	Check ground resistance for special weapons facilities at request of user. Check for low voltages and/or low power factor.	14-5 13-2
Electrician	Monthly or Annually	Inspect station (substation switchgear or UPS) as follows: (1) Check electrolyte level and add distilled water if needed. (2) Check charging rate. Adjust charging rate as necessary to maintain proper specific gravity. (3) Test for proper operation under simulated power interruption. Check maintenance free batteries. Check voltage, check and clean terrminal/connection.	 2-8-3

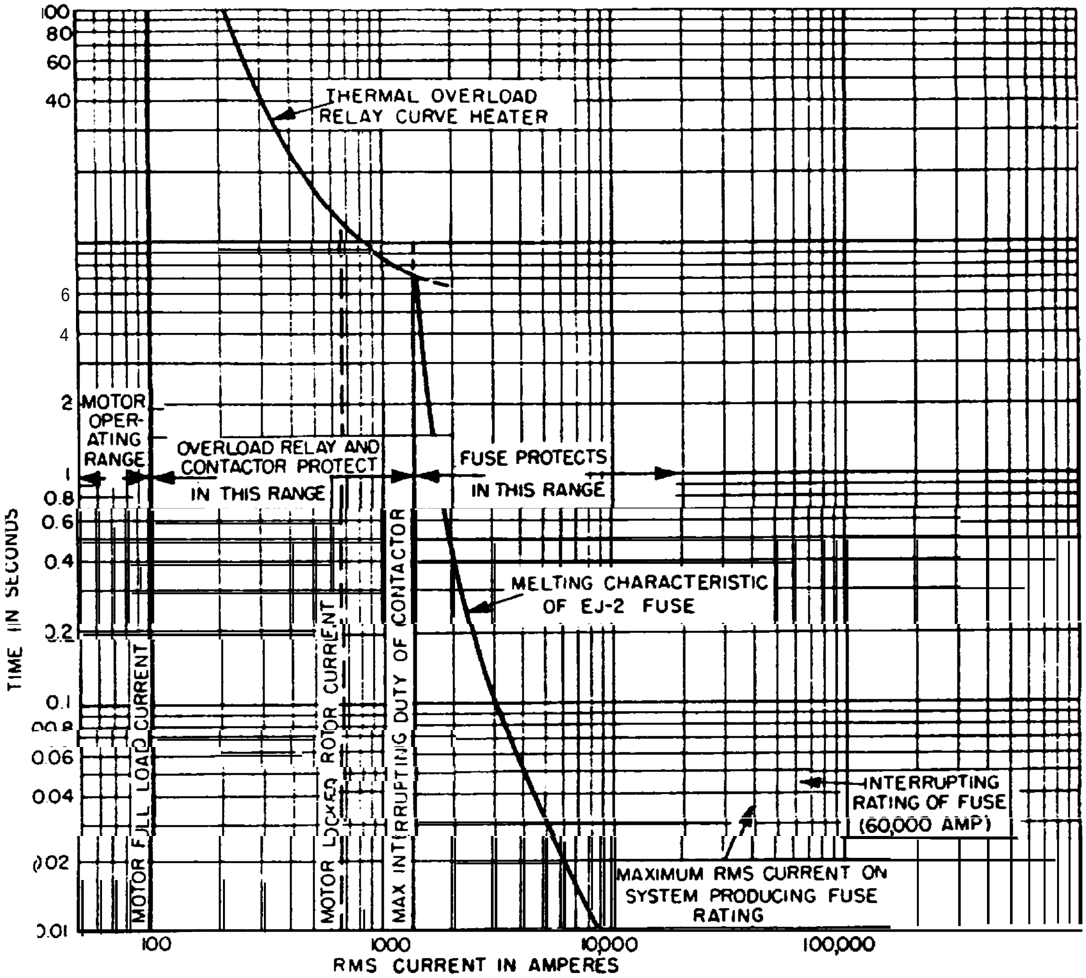
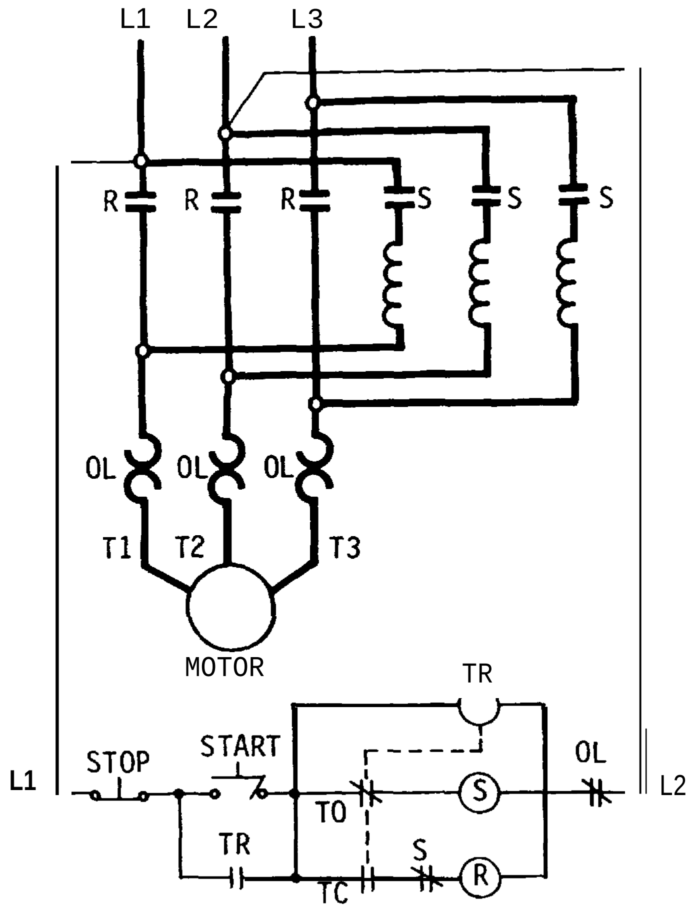


Figure 5-4. Coordination of motor overload relay and current limiting fuse.

rents. At military installations, they typically range in size from 5 to 200HP, and the voltage may vary from about 208V tQ 2300V. The autotransformer starter provides greater starting torque per ampere of starting current drawn from the line than any other reduced voltage motor starter. Two contractors are usually used for connection of an autotransformer starter. See figure 5-5. When the start push button is pressed, start contactor “S” closes. This contactor serves to connect the auto-transformer to the line, and the motor to taps on the autotransformer. After a defined timely delay governed by pneumatic timer TR, contactor “S” drops out, and run contactor “R” closes, connecting the motor directly across the line. At this time, the autotransformer is disconnected from both the line and the motor. It is important that contactor "S" is dropped out before contactor “R” closes since any overlapping of “R” and “S” in the closed position will result in a short circuited autotransformer secondary. This would cause high current to flow and subject that winding to high thermal and magnetic stresses. Standard autotransformers are equipped with taps which allow them to be adjusted to operate at different percents of line voltage. Small sizes are normally equipped with taps for 65 and 80 percent of line voltage, while larger sizes normally have 50, 65, and 80 percent taps.

(2) *Resistance starters.* This starter limits the starting current by employing resistors in series with the motor windings. This provides a smooth start and precise acceleration through a closed transition to full voltage and avoids a sudden mechanical shock to the driven load. Power and control circuits of a resistance motor starter are given in figure 5-6. When the start button is pressed, start contactor “S” connects the motor to the line with the starting resistor in series and a pneumatic timer is also picked up. After a time delay governed by timer TR, the TR/TC contacts close, Run contactor “R” closes, short-circuits the starting resistor, and connects the motor across the line.

(3) *part-winding starters.* These are used with squirrel cage motors having two separate, parallel stator windings (fig 5-7). The motor is started on one winding through accelerating contactor “lM” at



NOMENCLATURE

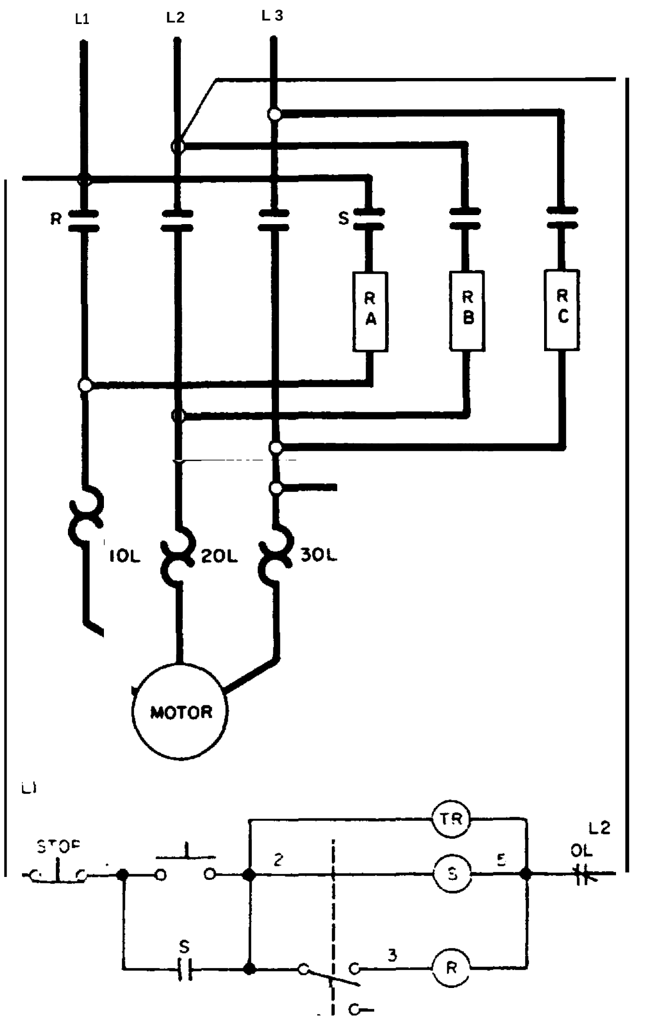
S	Start Contactor
R	Run Contactor
TR	Pneumatic Timer
OL	Overload Relay
TR/TO	Contact Stays-Closed When TR Picks Up; It Opens After A Time Delay.
TR/TC	Contact Stays Open When TR Picks Up; It Closes After A Time Delay.

Figure 5-5 Autotransformer starter.

about 2/3 of normal inrush current. After a period of acceleration governed by pneumatic timer TR, the other winding is energized through run contactor '2M". This operation permits the use of contactors which are half as large as those required for the reduced-voltage starters, resulting in approximately a 50 percent reduction in cost. However, the motor cannot carry its load until both windings are energized.

(4) *Wye-delta starters.* A variation on the part-winding starter is the wye-delta type, which starts the motor with the windings connected wye, and after a period of acceleration, reconnects the windings for normal delta operation. This type is limited to-wye-delta comectable motors but produces better starting torque at a lower inrush current and is used extensively with air-conditioning motors having a high inertia load and a long acceleration time.

(5) *Solid-state starters.* Solid-state starters (fig 5-8) provide smooth, stepless acceleration of squirrel cage motors from standstill to fill speed. It provides extended starting times by supplying continuously varying voltage to the AC motor from zero to full voltage. Controlled starting of a standard squirrel cage motor is accomplished by supplying reduced voltage to the motor terminals. This reduced



NOMENCLATURE

S START CONTACTOR
R RUN CONTACTOR
RA,RB,RC RESISTORS
TR PNEUMATIC TIMER
OL OVERLOAD RELAY

Figure 5-6. Resistance starter.

voltage produces reduced torque which means a slow, controlled acceleration. Typical applications that require lower controlled starting torques are large pumps, compressors, and heavy material handling conveyors.

e. Two-speed starters. This circuit allows a motor to be started at low speed before running it at high speed. Resistors might be utilized to provide a reduced-voltage start or a separate, lower line voltage may be available for low speed operation.

f. Starters and speed regulators for AC wound rotor and DC motors. This equipment is much more complex than the starting devices previously discussed. Specialized guidance is required to install and maintain this equipment. Consequently, the manufacturer's diagrams and instructions should be obtained and kept readily available.

g. Adjustable speed/frequency starters. AC adjustable speed operation is obtained by converting the fixed frequency AC line power into an adjustable voltage and frequency output which operates the AC motor at the desired speed. The input AC power is converted to adjustable DC voltage by a solid-state converter module. The DC power is then converted by the inverter to produce AC output power at an adjustable frequency and voltage suitable for operating either conventional AC induction motors or synchronous motors. Since the speed of an AC motor is a function of the applied frequency, accurate speed control is readily provided. These systems are complex and may induce harmonics on the electrical system which may, in turn, disrupt the operation of nearby equipment. Maintenance should be performed by personnel experienced with solid-state drives and controls.

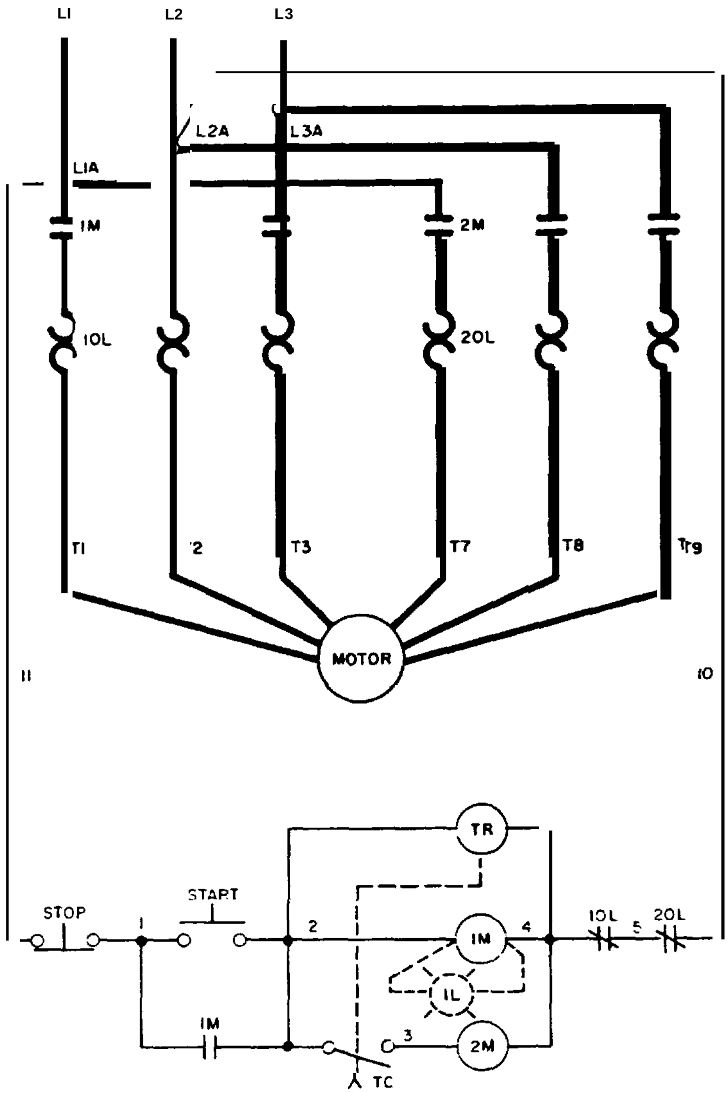
h. Miscellaneous types. Other terms used to describe motor controls include the following:

(1) Reversing starter. A motor that can be operated in either a clockwise or counterclockwise direction.

(2) Motor control center is the term given to a grouping of motor starters within a large enclosure (fig 5-9). The centers are used where several motors are to be operated from a single location. The starters themselves may be magnetic across-the-line starters or other types. A typical use would be in a boiler control room where the various fan, pump, conveyer, and other motors serving the boiler are all controlled from a central location.

5-3. Components and maintenance of motor controls.

Control equipment should be inspected and serviced simultaneously with the motors. As a general rule, overhaul procedures for control equipment are less involved than motor overhauling. Most repairs can be made on-site. Motor starters represent one area in which simplicity of construction and wiring has been emphasized by the manufacturers. Improvements have resulted in starters that are simple to install, maintain and operate. Connections are readily accessible, some parts are of plug-in type and may be easily replaced. Coils are often encapsulated in epoxy compounds and are less likely to burn out. Practically all newer starters have provisions for adding several auxiliary contacts with very little effort. Spare parts for starters are usually available from local suppliers. Spare starters, as



NOMENCLATURE

IM ACCELERATING CONTACTOR
2M RUN CONTACTOR
TR PNEUMATIC TIMER
OL OVERLOAD RELAY

Figure 5–7. Part-winding starter.

well as spare parts, for the most used types and sizes should be stocked in the regular shop supply channels.

a. Enclosures. Enclosures do not normally require maintenance when employed in a clean, dry and noncorrosive atmosphere. But in a marginal atmosphere, enclosures should be inspected and maintained as recommended in paragraph 2-2. The frequency of these inspections should be dictated by the corrosiveness of the atmosphere.

b. Electrical connections. Experience indicates that failures of electrical connections are the cause of many equipment burnouts and fires. Refer to paragraph 2–3 for recommended maintenance.

c. Molded case breakers. A wide variety of circuit breakers are used in the military services. Thermal-magnetic molded case circuit breakers (fig 5-10) are predominant in building panel boards and motor control centers. They are available in bolt-in or plug-in types and in single-pole for two-wire grounded circuits or multiple-pole for two and three-wire ungrounded or three and four-wire grounded circuits. Multiple units should be of the common trip type having a single operating handle. The need for maintenance on molded case breakers will vary depending on operating conditions. Molded case breakers are relatively trouble-free devices requiring little maintenance. For the most part, maintenance will require only that conductor terminations are tight and free from corrosion, and that the breaker is kept dry and free from excessive accumulations of dirt and dust. Because most breakers employ welded internal construction, they require no internal servicing. An exception to this is the trip unit, which is replaceable on breakers in larger frame sizes. Periodic inspection should be made to ensure that the trip unit hold-down bolts are tight. For breakers rated 100 amps and below, and where inspection indicates some type of repair is in order, "repair by replacement” is advisable.

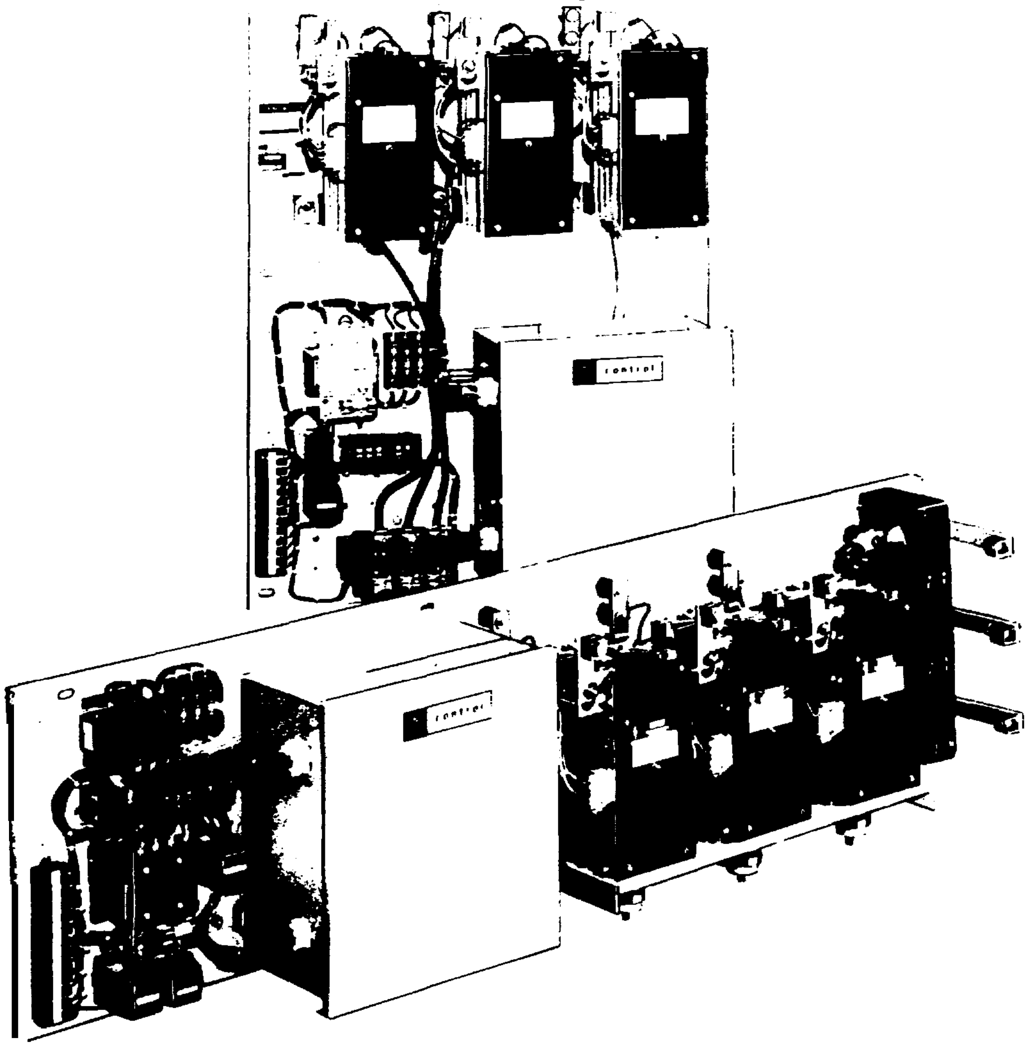


Figure 5-8. Solid-state starter

Small breakers are fairly low in cost, and labor costs do not justify repair. For larger sizes, replacement parts will include such items as handles, arc chutes, and trip units. Trip units are sealed to prevent tampering. Where a trip unit itself is found to be faulty, it should be replaced as a unit, rather than repaired. Some users maintain a regular program of calibration checks (verification testing) to verify the trip point. These tests can be performed on the plant premises. In conducting such tests, care should be taken to follow the manufacturer's specific instructions. Where conditions are not closely controlled, misleading results can be obtained. Test limits provided by the manufacturer must be observed. But, generally, it is advisable to operate and inspect the circuit breaker when maintenance of other components of the motor controls or panel board is being performed. Recommended procedures are routine testing and verification testing. These two types of testing are optional and are implemented at selected locations depending upon the operating environment or critical load being served.

(1) *Routine field testing.* The following constitutes a guide for the types of tests which might be performed during routine maintenance of molded-case breakers. The tests recommended are based on proven standard maintenance practices and are aimed at assuring that the breaker is functionally operable. All tests are to be made only on breakers and equipment that are de-energized. Extreme atmospheres and conditions may reduce the dielectric strength of any insulating material including those of which molded case breakers are made. Therefore, the first routine check recommended is an insulation resistance test (para 14-2). The voltage recommended for this test should be at least 50 percent greater than the breaker rating. However, a minimum of 500 volts is permissible. Tests should be made between phases of opposite poles as well as from current-carrying parts of the circuit breaker to ground. Also, a test should be made between the

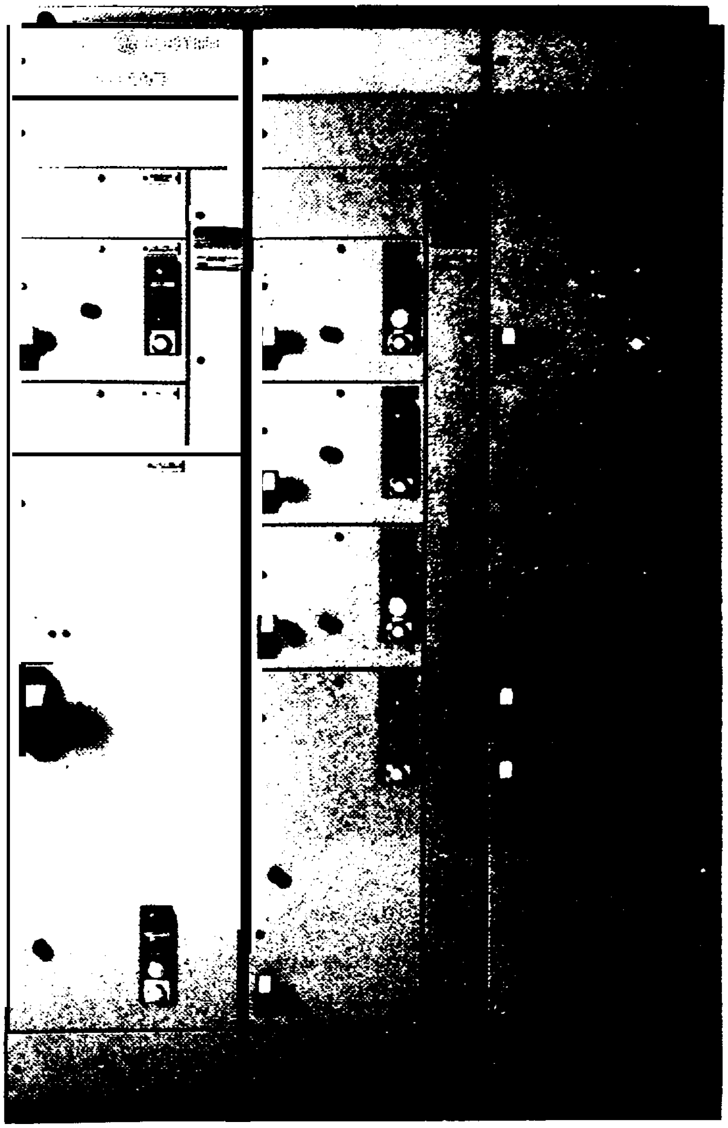


Figure 5-9. Typical motor control center.

line and load terminals with the breaker in the open position. Resistance values below one megohm per kV of test voltage are considered unsafe and should be investigated for possible contamination on the surfaces of the molded case of the circuit breaker. Clean the molded case surface and retest. If low megohm readings persist, then replace the breaker. For individual breaker resistance readings, load and line conductors should be disconnected from the breaker under test. If not disconnected, the test measurements will also show resistance of the attached circuit. During routine testing, all circuit breakers should be operated (while documenting) several times to ensure that the contacts are not frozen and that the mechanical components function without undue friction. This action will also lessen the effect of any film that might have built up on the contacts. Check for cracked, warped or broken case and replace if necessary. If there is evidence of internal heating, or reason to suspect high contact resistance or improper calibration, the breakers should be replaced. It is recommended that molded-case breakers with removable covers be checked for contact and latch cleanliness as well as connection tightness. Lubrication should be checked. If the operating mechanism appears dry, apply a drop of heavy oil or light grease at the wear points. Do not apply lubricant to the contacts or to the trip unit. If the contacts are badly pitted, they should be cleaned with a fine file or sandpaper. Be sure to avoid any accumulation of filings in the breaker. Do not tamper with factory sealed breakers.

(2) *Verification field testing.* Verification field testing of molded case circuit breakers is intended to check breaker operation versus manufacturer's published data. If molded case circuit breaker performance characteristics are to be tested in the

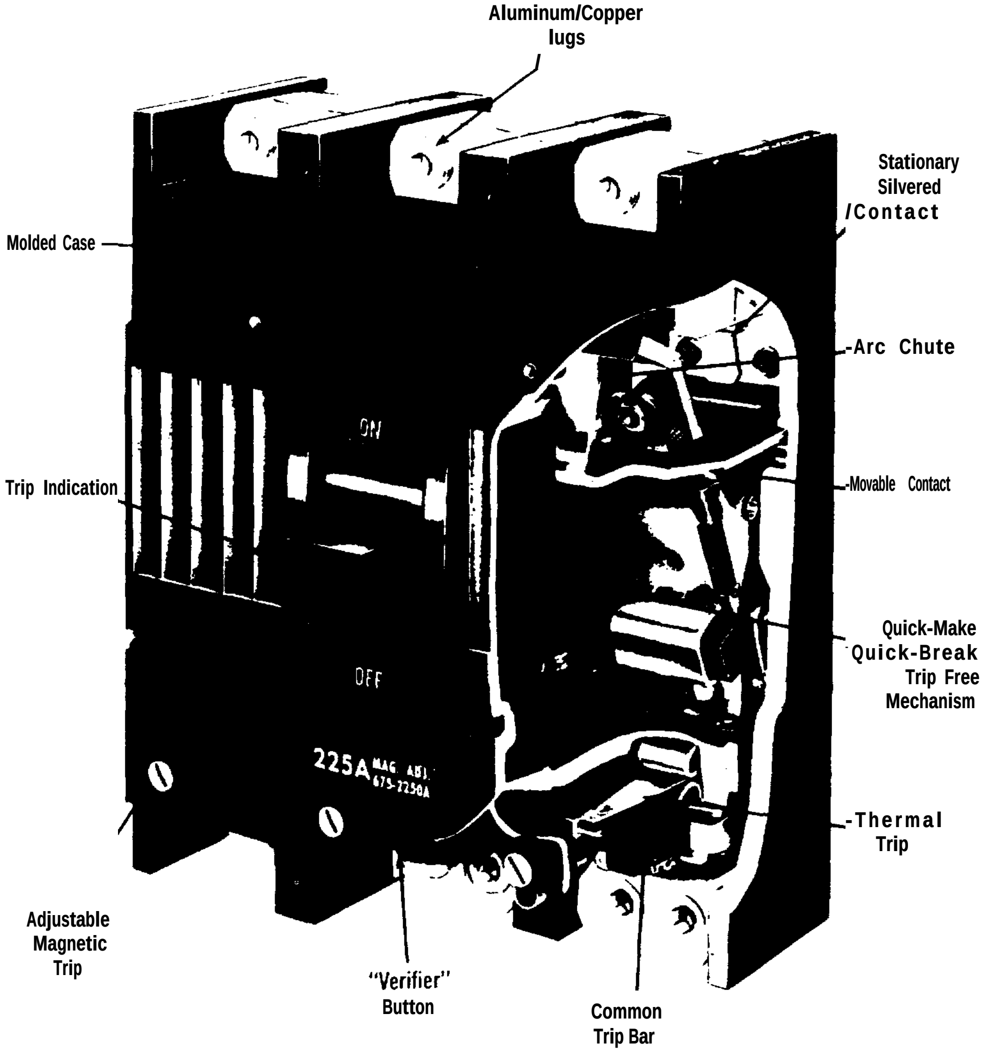
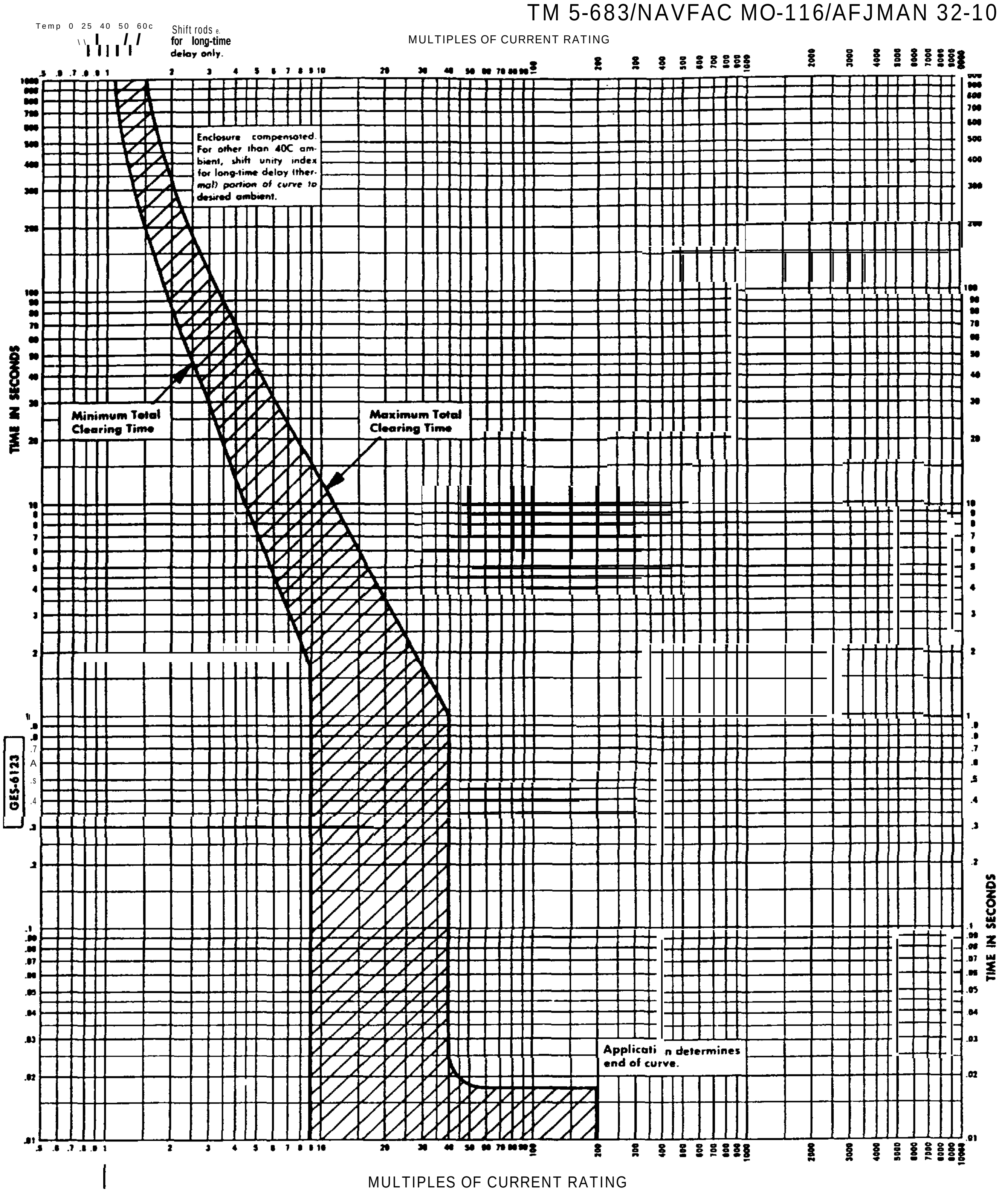


Figure 5–10. Cutaway view of typical molded case circuit breaker.

field, there are many variables that must be recognized and taken into account. Underwriters Laboratories, Inc. (UL) "Standard for Branch Circuit and Service Circuit Breakers" (#489) is the basis for performance standards for all molded case circuit breakers bearing the UL label. Anyone testing molded case circuit breaker performance characteristics should study these standards and be familiar with the conditions specified for the qualifying tests. The principal purpose of field testing is not to determine if the breakers exactly meet the manufacturer's published curves but rather to determine if the device is furnishing the protection for which it was installed; namely, the protection of that part of the electrical system to which it is applied. For instance, a circuit breaker that trips in less than the minimum time shown by the manufacturer's trip time curve may furnish more protection than expected. When field testing circuit breakers, it is recommended that the overcurrent trip test be performed at 300 percent of rated current. The reaction of the circuit breaker to this overload is indicative of its reaction throughout its entire overcurrent trip range. The 300 percent load is chosen as the test point because it is relatively easy to generate the required current in the field. Also, the wattage per pole from line to load is small enough so the dissipation of heat in the non-active pole spaces is minor and does not appreciably affect the testing results. Various test equipment and test procedures are available for molded-case circuit breaker testing (refer to the circuit breaker manufacturer for recommended testing equipment and procedures). Test equipment generate high currents at low voltages and are safe and convenient to use for field testing. For specific minimum and maximum tripping times given 300 percent current flow, refer to the manufacturer's document for the breaker being tested (fig 5–11). If the breaker does not trip within the specified bandwidth, then the breaker should be replaced. The instantaneous magnetic trip characteristics of the breaker can be influenced by stray



GENERAL ELECTRIC	MOLDED-CASE CIRCUIT BREAKER	GES-6123
Current Ratings 50, 60, 70 and 80 Amperes **Voltage Ratings** 240 Volts A-c **Frequency Rating** 60 Hertz	**E 100 LINE** **Type TEB, 50-80 Amperes** **Long-time Delay and Instantaneous** ***Time-current Curves*** (Curves show enclosure-compensated circuit breaker in open air, 40C ambient, wired with conductors of corresponding rating, no prior load. For all other ambients, use shift index at top of sheet.)	**Adjustments** Long-time delay thermal trip: not adjustable. Instantaneous magnetic trip: not adjustable.

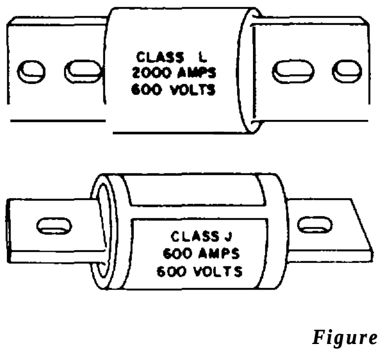
Figure 5-11. Molded case circuit breaker time-current curve.

magnetic fields. The test setup must be conducted in such a way that magnetic fields created by the test equipment, steel enclosures, or the conductors from the test equipment to the circuit breaker do not affect the test results.

d. Fuses. Fuses are among the oldest types of overcurrent protectors. They are simple, rugged and inexpensive. They sense overcurrent conditions through the development of heat in the conducting elements and accomplish their operation by destruction of these elements. They offer both long-time and short-time short circuit protection and are used widely in the protection of small motors. Maintenance of fuses should not be performed until all power sources are disconnected (fig 5-12). At that time, check the continuity of all fuses with an ohmmeter. A reading greater than zero ohms indicates that the fuse is blown and must be replaced. Inspect fuse terminals and fuse holder clips. Check that the portions of the fuse making contact in the clip are clean and bright; poor contact can cause overheating which results in a discoloration of the contact surfaces. If this occurs, then the oxidized surfaces should be cleaned and polished. Silver-plated surfaces should not be cleaned with an abrasive material. Wiping contacts with a noncorrosive cleaning agent is recommended. Tighten all fuse holder connections. Fuse clips should exert sufficient pressure to maintain good contact, which is essential for proper fuse performance. Clips which make poor contact should be replaced. Clip clamps are recommended when unsatisfactory clips cannot be replaced. Replace fuses showing signs of deterioration such as discolored or damaged casings or pitted contact surfaces. There are many types of fuses (fig 5-13) with various characteristics, some of which are physically interchangeable. Make certain that fuses are of the proper type and rating. Never replace one type of fuse arbitrarily with another type fuse of the same physical size simply because it fits the fuse holder. A continuity check should also be performed on replacement fuses to ensure their integrity. Fuses should have correct current and voltage ratings, proper time-delay or current-limiting characteristics and an adequate interrupting rating to protect the circuit and its components Current ratings of fuses protecting transformers or motors should be selected at or near the fill load current. Voltage ratings of fuses should equal or exceed their circuit voltage. Interrupting ratings of fuses should equal or exceed the available fault current at the fuse holder. UL listed fuses without marked interrupting ratings are satisfactory only on circuits where fault currents do not exceed 10,000 amperes. Non-current-limiting fuses should not be used to replace current-limiting fuses since fuse holders for UL listed current-limiting fuses are designed to reject fuses which are not current limiting. Fuse holders and rejection clips should never be altered or forced to accept fuses which do not readily fit. An adequate supply of spare fuses, especially those which are uncommon, will minimize improper replacement.

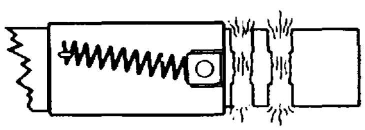
PREVENTIVE MAINTENANCE

- IS FUSE TIGHT IN CIRCUIT?
- ARE FUSE AND HOLDERS CLEAN AND DRY?
- OVERHEATING?
- ARE RIGHT TYPE AND SIZE IN CIRCUIT?
- **ARE SPARES HANDY?**

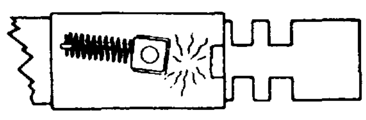


CORRECTIVE MAINTENANCE

- TEST FOR CONTINUITY, SINGLE PHASING
- WHAT OPENED FUSE?
  -- SHORT?



  -- OVERLOAD?



  -- HIGH TEMPERATURE DERATING?
- REPLACE WITH RIGHT TYPE AND SIZE.

Figure 5-12. Fuse maintenance practices.

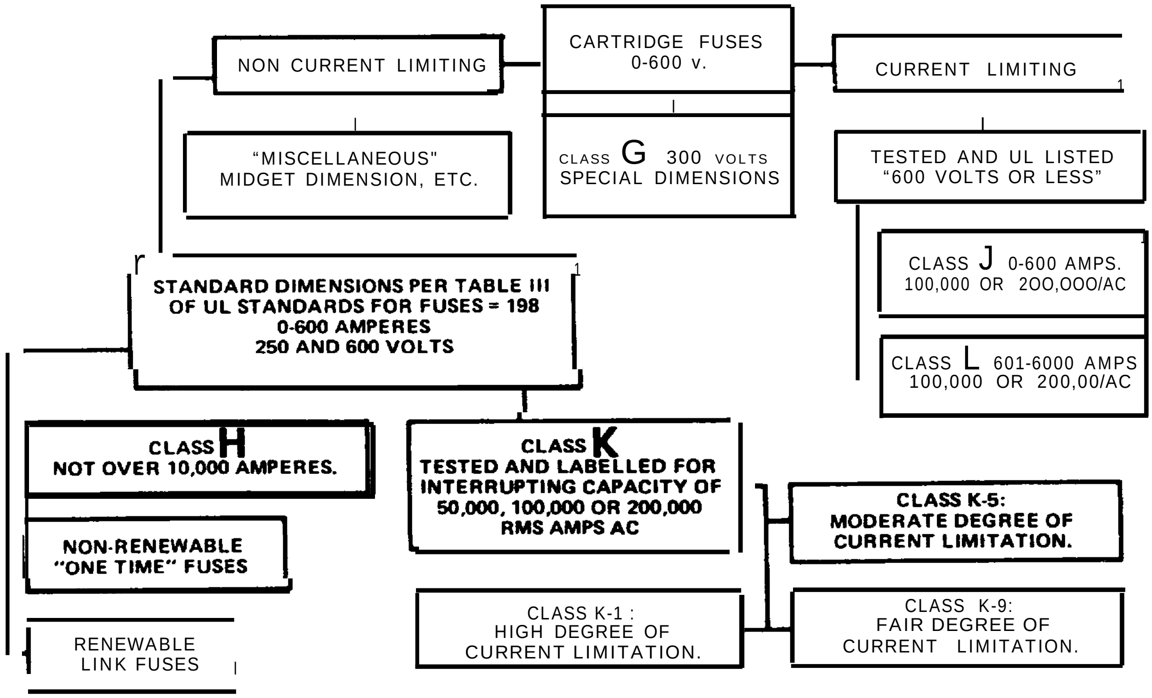


Figure 5-13. Underwriters' Laboratories cartridge fuse classification.

e. Thermal overloads. Thermal overload relays contained in starters provide more precise motor protection against overloads and momentary surges than fuses or circuit breakers. However, they do not provide short circuit protection. Relays themselves require little maintenance other than occasional testing to ensure that they are operational. Thermal overloads should be checked and resized whenever the motor is replaced to adequately protect the motor. The relays are controlled by heater elements (fig 5-14) which are in series with the motor current. The size of the heater must match the motor being protected. Be especially careful if the motor has been oversized to compensate for lower load current with lower rated heaters to cause tripping on loss of one phase (single phasing). It often happens that the wrong size heaters are installed. If the heater is too small, the overload relays act to take the motor off line unnecessarily. If too large, the motor will operate without proper protection and could be damaged from overload. If the relays frequently operate to take the motor off line, the heaters should be checked first. If the heaters are properly sized (about 120 percent of motor full load current) and there are no unusual temperature conditions, then check the motor current. If the motor current is higher than the nameplate rating by a margin sufficient to exceed the heater rating, then the relay is operating properly, and the motor is either overloaded or in fault, therefore, check the motor. Do not put in larger heaters. If however, the motor stops frequently even though the heaters are correctly sized and the line current and ambient temperature are normal, then check the relays. The relays should be tested and replaced if required. Unfortunately, the overload relays that serve as safety valves to protect the motors from burnouts due to faults and overloads, sometimes fail to respond properly. For example, aging and inactivity followed by metal fatigue in some relay types may result in a failure to operate under conditions of overload. Periodic testing of the relays under load conditions, checking the tightness of all overload connections and inspecting for contact overheating and cleanliness forms an important part of a good motor control maintenance program. Suitable test instruments are available that provide a dummy load to the relay and measure the time interval required to open the contacts. Their use is highly recommended, especially on relays for motors that serve critical loads; e.g., motors driving air conditioners which are used for communication or data processing equipment, or motors on production lines. For most applications, testing of motor overload relays should be conducted every 2 years. Regular testing of thermal overload motor relays is a recommended procedure for all installations. Overload relays employ a thermal element designed to interpret an overheating condition in the motor winding by converting the current in the motor leads to heat in the overload relay element. As the heat in the element approaches a predetemnined value, the control circuit to the magnetic contactor holding coil is interrupted and the motor branch circuit is opened. The

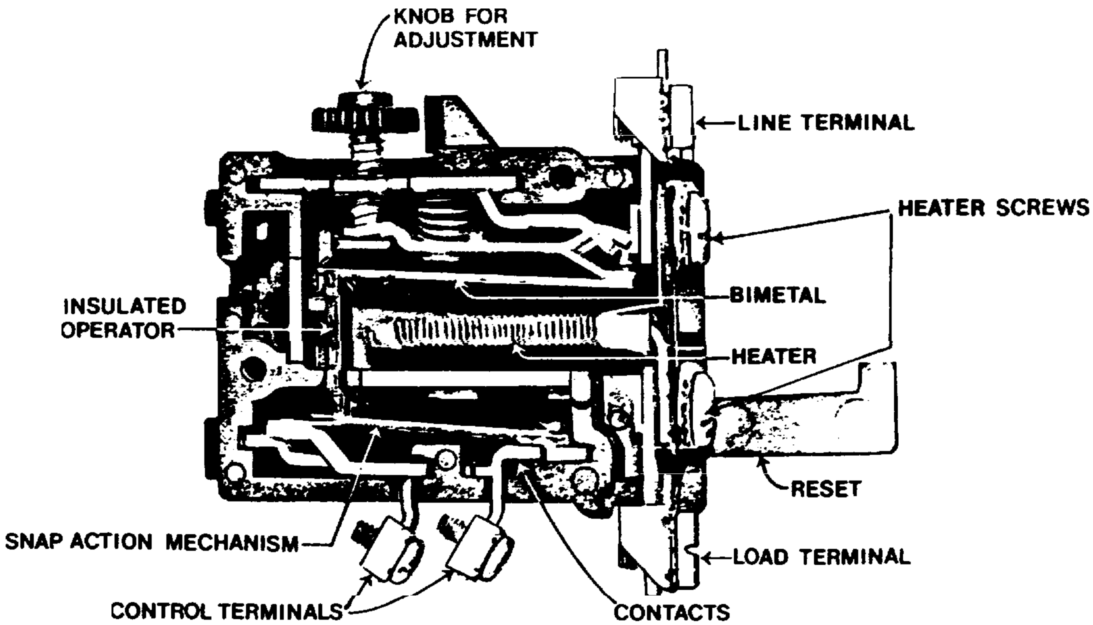


Figure 5-14. Typical terminal overload.

controller and motor should be located in the same ambient temperature environment so that the overload relay can act accurately. If the controller is located in a lower ambient temperature environment than the motor, it may not trip in time to protect the motor. Vice versa, if the controller is in a higher ambient temperature than the motor, it will trip even if the motor is not in overload. The significant different ambient temperatures of the motor and controller can be compensated by selection of a relay heater or use of a relay that compensates for temperature. The adjustments are to decrease the motor current protection (lower trip setting) by one percent for each degree Celsius the motor ambient exceeds the controller normal ambient temperature or increase the motor current protection (raise trip setting) by one percent for each degree Celsius the controller ambient exceeds the motor ambient. The manufacturer's published heater selection tables should be referenced (fig 5-15). It should be noted that in this case, according to the National Electrical Code, a disconnecting means must be located in sight from the controller location.

f. Contractors. The part of the starter that contains the coil and contacts is known as the contactor (fig 5-16). It *is* used to control the circuits to the motor. Contractors are intended for repetitive operation, perhaps as many as a million or more operations. Normal wear and tear can be expected, and therefore periodic inspections should be made to ensure that all moving parts are functioning. properly.

(1) *Copper contacts.* Copper contacts should be replaced when worn thin or badly burned and pitted. Both the moving and the stationary contacts should be replaced to avoid possible misalignment of an old contact with a new one. Check the contact spring pressure with a scale in accordance with the manufacturer's recommendations. Adjust or replace the springs as necessary to maintain good pressure between pairs of contacts. When copper contacts become excessively rough, they should be smoothed with a burnishing tool or a fine file designed for this purpose. Do not use emery cloth. Also, any copper oxide on the contact surfaces should be removed. Copper oxide is not sufficiently conductive, it acts as a high resistance and could eventually cause overheating. When filing, particular care should be taken to maintain the original shape of the contacts. It is not necessary to develop smooth contact surfaces. In fact, better operation is obtained when the surfaces are rough dressed. Contacts should not be lubricated.

(2) *Silver contacts.* Silver contacts should not be filed. Silver oxide, that forms on the contact surfaces, does not have to be removed because it is a good conductor. Routine inspection should always include checks for tightness of terminal and cable connections as well as for signs of overheating. Replacements should be made as conditions dictate. Manufacturer's recommendations should be followed closely for maintenance and replacement of parts.

(3) *Shunts.* Shunts are flexible bands of woven copper strands carrying current from the moving contacts to a stationary stud. If the shunt is unduly bent or strands are broken, then it should be replaced.

(4) *Coils.* Coils require very little maintenance. In fact it is generally more economical to replace the

FOR CR124 C

Max Motor Full-load Amperes	Heater Cat. No. CR123	Max Fuse Rating	Max Motor Full-load Amperes	Heater Cat. No. CR123	Max Fuse Rating
.33	C0.36A	3	13.5	C13.7B	45
.37	C0.39A	3	14.6	C15.1B	45
.41	C0.43A	3	16.1	C16.3B	50
.46	C0.48A	3	17.9	C18.0B	60
.52	C0.54A	3	19.3	C19.8B	60
.57	C0.60A	3	20.6	C21.4B	70
.61	C0.66A	3	22.6	C22.8B	70
.67	C0.71A	3	24.8	C25.0B	80
.75	C0.78A	3	27.6	C27.3B	90
.84	C0.87A	3	30.0	C30.3B	90
.94	C0.97A	3			
1.03	C1.09A	3			
1.14	C1.18A	3			
1.30	C1.31A	3			
1.42	C1.48A	3			
1.61	C1.63A	6			
1.72	C1.84A	6			
1.93	C1.96A	6			
2.10	C2.20A	6			
2.34	C2.39A	6			
2.64	C2.68A	10			
2.86	C3.01A	10			
3.13	C3.26A	10			
3.32	C3.56A	10			
3.68	C3.79A	10			
4.08	C4.19A	15			
4.61	C4.66A	15			
5.21	C5.26A	20			
5.62	C5.92A	20			
6.12	C6.30A	20			
6.83	C6.95A	25			
7.70	C7.78A	25			
8.48	C8.67A	30			
9.19	C9.55A	30			
9.92	C10.4B	30			
11.1	C11.3B	35			
12.2	C12.5B	40			

FOR CR124 D

Max Motor Full-load Amperes	Heater Cat. No. CR123	Max Fuse Rating
6.63	C6.95A	20
7.59	C7.78A	20
8.39	C8.67A	25
9.20	C9.55A	30
9.93	C10.4B	30
11.2	C11.3B	35
12.5	C12.5B	40
14.1	C13.7B	40
15.5	C15.1B	50
17.4	C16.3B	50
19.8	C18.0B	60
21.2	C19.8B	70
22.7	C21.4B	70
24.9	C22.8B	80
27.3	C25.0B	80
29.7	C27.3B	90
34.2	C30.3B	100
40.2	C33.0B	110
46.3	C36.6B	125
50.0	C40.0B	150

Figure 5-15. Typical heater selection table for thermal overload device.

coil than it is to attempt repairs. Coils will operate efficiently at 85 to 110 percent of rated voltage. Higher voltages shorten life and lower voltages may result in failure to close the contacts completely. This could result in welded contacts. Coil burnout also could occur if the contactor fails to close properly either from being blocked or by low voltage. In either case, the current flowing through the coil is larger than rated because of the larger air gap in the magnetic circuit. Maintenance consists of cleaning out accumulated dust and grease, if any, and inspecting the coil to see that it is of proper rating and operates properly. When handling coils, do not pick the coil up by its leads. If coils become wet, they should be dried out by spraying a contact cleaning chemical on the coil or by heating the coil in an oven at 110 degrees C to 125 degrees C. If it is necessary to varnish coils, use only an approved insulating treatment applied while the coils are still warm from baking. These instructions on drying and varnishing coils do not apply to the newer encapsulated types.

5-4. Preventive maintenance and troubleshooting guide.

Table 5-1 outlines typical preventive maintenance for a motor control. Table 5-2 lists troubleshooting and corrective maintenance practices.

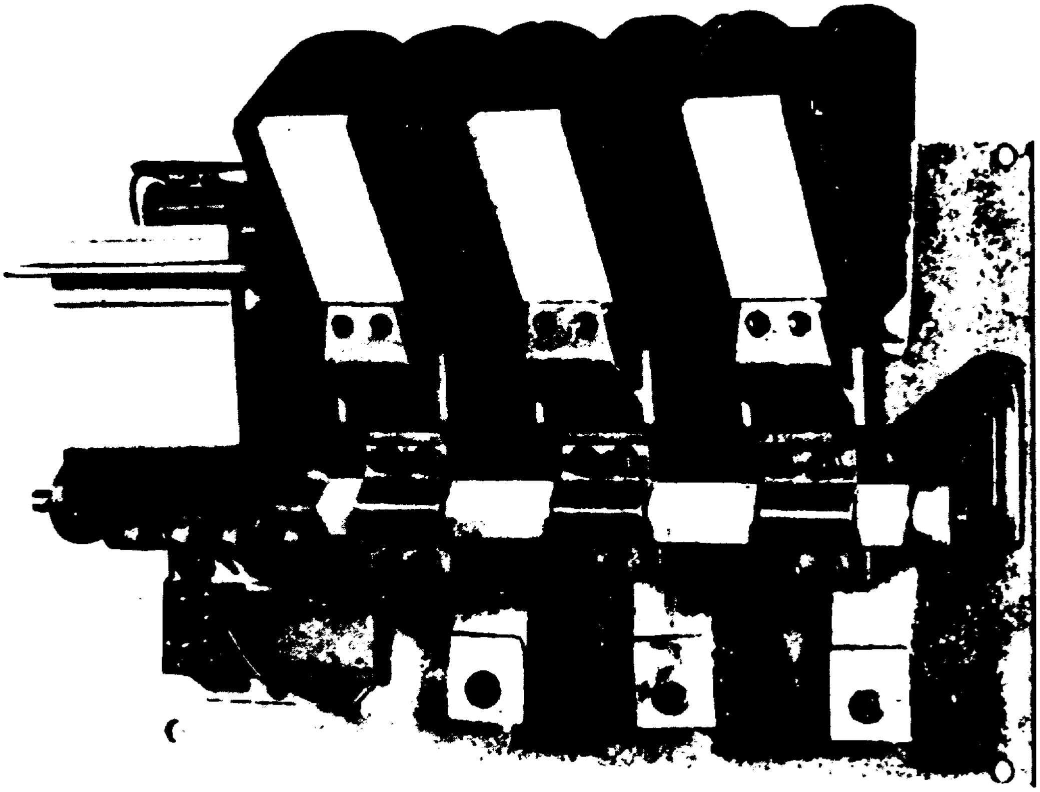


Figure 5-16. A NEMA size 6 magnetic contactor (Courtesy of Siemens-Allis).

Table 5-1. Motor control preventive maintenance guide.

WHAT TO INSPECT	WHAT TO INSPECT FOR
1. Exterior and Surroundings	Dust, grease, oil; high temperature; rust and corrosion; mechanical damage; condition of gaskets, if any.
2. Interior of Enclosure, Nuts and Bolts	Same as for No. 1 plus excess vibration which may have loosened nuts, bolts or other mechanical connections.
3. Contactors, Relays, Solenoids	
a. General	Check control circuit voltage; inspect for excess heating of parts evidenced by discoloration of metal, charred insulation or odor; freedom of moving parts; dust, grease, and corrosion; loose connections.
b. Contact Tips	Check for excessive pitting, roughness, copper oxide; do not file silver contacts.
c. Springs	Check contact pressure; is pressure same on all tips.
d. Flexible leads	Look for frayed or broken strands; be sure lead is flexible - not brittle.
e. Arc Chutes	Check for breaks or burning.
f. Bearings	Check for freedom of movement; do not oil.
g. Coils	Look for overheating, charred insulation or mechanical injury.
h. Magnets	Clean faces; check shading coil; inspect for misalignment, bonding.

Table 5-1. Motor control preventive maintenance guide continued.

WHAT TO INSPECT	WHAT TO INSPECT FOR
4. Fuses and Fuse Clips	Check for proper rating, snug fit; if copper, polish ferrules; check fuse clip pressure.
5. Overload Relays	Check for proper heater size; trip by hand; check heater coil and connection; inspect for dirt, corrosion.
6. Pushbutton Station and Pilot Devices	Check contacts, inspect for grease and corrosion.
7. Dashpot-Type Timers and Overload Relays	Check for freedom of movement; check oil level.
8. Resiators	Check for signs of overheating; loose connections; tighten sliders.
9. Connections	Tighten main line and control conductor connection; look for discoloration of current-carrying parts.
10. Control Operation	Check sequence of operation of control relays; check relay contacts for sparking on operation; check contacts for flash when closing; if so, adjust to eliminate contact bounce; check light switches, pressure switches, temperature switches, etc.

Table 5-2. Motor control troubleshooting chart.

CAUSE	REMEDY
1. Contactor or Relay Does not Close	
No supply voltage.	Check fuses and disconnect switches.
Low voltage.	Check power supplY. Wire may be to small.
Coil open or shorted.	Replace.
Wrong coil.	Check coil number.
Mechanical obstruction.	With power off, check for free movement of contact and armature assembly.
Pushbutton contacts not making.	Clean or replace if badly worn.
Interlock or relay contact not making.	Adjust or replace if badly worn.
Loose connection.	Turn power off first, then check the circuit visually with a flashlight.
Overload relay contact open.	Reset
2. Contactor or Relay Does Not Open	
Pushbutton not connected correctly.	Check connections with wiring diagram.
Shim in magnetic circuit (DC only) worn, allowing residual magnetism to hold armature closed.	Replace.
Interlock or relay contact not opening circuit.	Adjust contact travel.
"Sneak" circuit.	Check control wiring for insulation failure.
Gummy substance on pole faces.	Clean with solvent.
Worn or rusted parts causing burning	Replace parts.
Contacts weld shut.	See Item 3.

Table 5-2. Motor control trouble-shooting chart-continued.

CAUSE	REMEDY
3. Contacts weld shut or freeze	
Insufficient contact spring pressure causing contacts to burn and draw arc on closing.	Adjust, increasing pressure. Replace if necessary.
Very rough contact surface causing current to be carried by too small an area.	Smooth surface or replace if badly worn.
Abnormal inrush of current.	Use larger contactor or check for grounds, shorts or excessive motor load current.
Rapid jogging.	Install larger device rated for jogging service or caution operator.
Low voltage preventing magnet from sealing.	Correct voltage condition. Check momentary voltage dip during starting.
Foreign matter preventing contacts from closing.	Clean contacts with approved solvent.
Short circuit.	Remove short circuit fault and check to be sure fuse or breaker size is correct.
4. Contact Chatter	
Broken pole shader.	Replace.
Poor contact in control circuit.	Improve contact or use holding circuit interlock (3-wire control).
Low voltage.	Correct voltage condition. Check momentary voltage dip during starting.
5. Arc Lingers Across Contacts	
If blowout is series, it may be shorted.	Check wiring diagram to see kind of blowout.
If blowout is shunt, it may be open circuited.	Check wiring diagram through blowout.
Arc box might be left off or not in correct place.	See that arc box is on contactor as it should be.
If no blowout used, note travel of contacts.	Increasing travel of contacts increases rupturing capacity.

Table 5-2. Motor control trouble-shooting chart-continued.

CAUSE	REMEDY
6. Excessive Corrosion of Contacts	
Chattering of contacts as a result of vibration outside the control cabinet.	Check control spring pressure and replace spring if it does not give rated pressure. If this does not help, move control so vibrations are decreased.
High contact resistance because of insufficient contact spring pressure.	Replace contact spring.
7. Abnormally Short Coil Life	
High Voltage.	Check supply voltage and rating of controller.
Gap in magnetic circuit (alternating current only).	Check travel of armature. Adjust SO magnetic circuit is completed.
Ambient temperature too high.	Check rating of contact. Get coil of higher ambient rating from manufacturer, if necessary.
Filing or dressing.	Do not file silver-faced contacts. Rough spots or discoloration will not harm contacts.
Interrupting excessively high currents.	Install larger device or check for grounds, shorts or excessive motor currents. Use silver-faced contacts.
Excessive jogging.	Install larger device rated for jogging or caution operator.
Weak contact pressure.	Adjust or replace contact springs.
Dirt on contact surface.	Clean contact surface.
Short circuits.	Remove short circuit fault and check for proper fuse or breaker size.
Loose connections.	Clean and tighten.
Sustained overload.	Install larger device or check for excessive load current.
8. Panel and Apparatus Burned by Heat From Resistor	
Motor being started frequently	Use resister of hiqher rating.

Table 5-2. Motor control trouble-shooting chart-continued.

CAUSE	REMEDY
9. Coil Overheating	
Overvoltage or high ambient temperature.	Check application and circuit.
Incorrect coil.	Check rating and replace with proper coil if incorrect.
Shorted turns caused by mechanical damage or corrosion.	Replace coil.
Undervoltage, failure of magnet to seal in.	Correct pole faces.
Dirt or rust on pole faces increasing air gap.	Clean pole faces.
10. Overload Relays Tripping	
Sustained overload.	Check for grounds, shorts or excessive motor currents.
Loose connection on load wires.	Clean and tighten.
Incorrect heater.	Relay should be replaced with correct size heater unit.
11. Overload Relay Fails to Trip	
Mechanical binding, dirt, corrosion, etc.	Clean or replace.
Wrong heater or heaters omitted and jumper wires used.	Check ratings. Apply proper heaters.
Motor and relay in different temperatures.	Adjust relay rating accordingly or make temperature the same for both.
12. Noisy Magnet (Humming)	
Broken shading coil.	Replace shading coil.
Magnet faces not mating.	Replace magnet assembly or realign.
Dirt or rust on magnet faces.	Clean and realign.
Low voltage.	Check system voltage and voltage dips during starting.